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Comparison between reverse osmosis and membrane distillation for bilge water treatment

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Introduction

Bilge water is an effluent from engine rooms of ships characterized by a high content of oils, which need to be removed before water discharge into the sewer or navigable waters. Its composition can vary, but generally it is a wastewater with oil/grease, suspended solids, heavy metals and detergents. In addition, bilge water is a mixture of fresh and seawater, thus, being very corrosive and different from other types of oily wastewater found in the petrochemical and automotive industries or in domestic sewage operations. Therefore, it is more appropriate to refer to bilge water as an oily brine [1]. The methods commonly used for oily wastewater treatment can be classified as traditional methods (coalescence, coagulation, filtration and adsorption) and modern methods based on the membrane technologies such as reverse osmosis, nanofiltration and ultrafiltration [2]. Much work has been also conducted for oily wastewater using microfiltration (MF) with organic/inorganic membranes [1,3]. Especially ceramic membranes are very efficient due to the ability to accomplish the current regulatory treatment objectives with no chemical pretreatment and higher fluxes compared to organic membranes. In addition a high mechanical, thermal and chemical resistance of ceramic membranes allows for a better recovery of membrane performance [3]. Among several processes applied to bilge water treatment reverse osmosis and membrane distillation are very promising, since they allow producing clean water, which not only meets regulations for a discharge but also for its reuse. This experimental study of the integrated membrane process for bilge water treatment focuses on comparison of reverse osmosis (RO) and membrane distillation (MD) processes. Since permeate flux in a RO process is controlled by the osmotic pressure of treated water, a high water recovery can not be achieved for bilge water with an elevated salinity. Membrane distillation process (MD), where osmotic pressure is not a limiting factor, allows for a significant increase in water recovery. In this work permeate flux and removal of inorganic and organic compounds were investigated as function of pressure and volume concentration factor (VCR), for MF and RO processes, and temperature for a MD process. Membranes behaviour was evaluated with filtration time and with increasing VCR.

Methods

This study was conducted with real bilge water characterized by a relatively high salt content (conductivity of about 14 mS/cm). Bilge water was first treated by a MF process with ceramic membranes (average pore size 0.2 μm) from TAMI Industries (France). Obtained MF permeate was used as a feed for a reverse osmosis/nanofiltration (RO/NF) process, operated with different types of polymeric spiral wound modules (size 40”x4”) and small samples of flat sheet NF and RO membranes, all produced by Dow-Filmtec (USA). In our study RO concentrate of bilge water was treated by a MD process with Accurel PP 2E membrane ($S=0{,}0063m^2$).

Results and discussion

MF experiments with two ceramic membrane modules arranged in series showed a highly stable permeate flux and permeate quality when increasing VCR up to 15. RO experiments were conducted with MF permeate. Prior to tests with a spiral wound module, a test cell

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experiment with a flat sheet sample of the same membrane type was performed. Permeate flux showed a linear increase with pressure, while conductivity retention reached its asymptotic value of about 99.75 % when pressure was raised from 20 to 50 bar. In addition, permeability to water measured before and after the bilge water experiment was similar, thus no severe membrane fouling was expected when using MF pre-treated bilge water. RO experiment with a spiral wound membrane module conducted in a concentration mode (concentrate recycled to the feed) revealed that permeate flux decreases very fast with VCR. When VCR reached value of ~4.5, permeate flux decreased from initial value of ~20 L/m^{2}h at 30 bar to 7 L/m^{2}h at 50 bar. Decrease in permeate flux imposed decline in conductivity retention from 99% to 96.5%.

In the MD process a very low permeate salinity and a high permeate flux, stable over experimental time, were observed when process was conducted with RO concentrate obtained with microfiltrated bilge water (conductivity of ~44.8 mS/cm). The results of temperature influence on permeate flux and retention are presented in Figure 1.

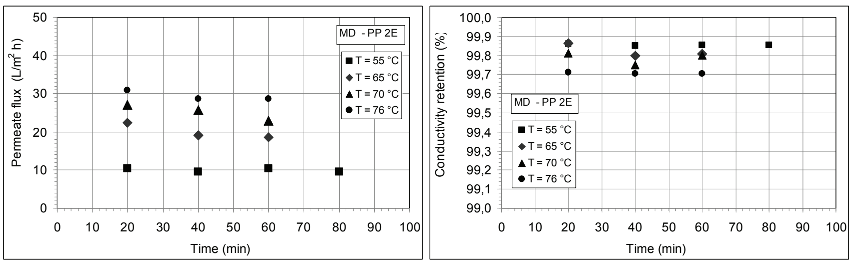

Figure 1. Permeate flux (left) and conductivity retention (right) as function of time during MD with bilge water at various temperatures (cond. 44.8 mS/cm) and PP 2E membrane (S=0,0063m^2).

To further compare performance of RO and MD processes, several measurements of permeate flux and salt retention were conducted using bilge water. The results presented in Fig. 2 revealed that the MD process offers a much higher permeate flux, even at low temperature of 55°C, and a much higher and constant conductivity retention when compared with the RO process at 30 bar. Also retention of TOC and COD was found excellent and their concentration in treated bilge water was lower than discharge limits for the Italian law.

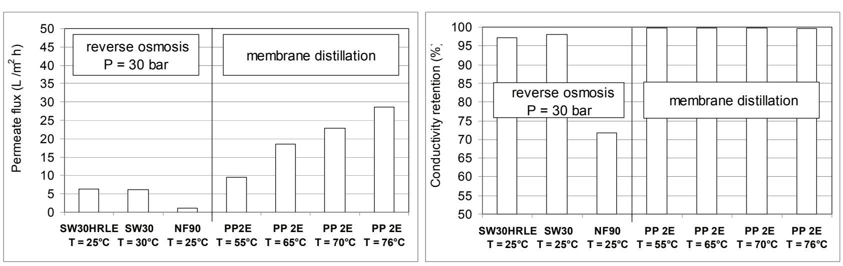

Figure 2. Comparison of permeate flux (left) and conductivity retention (right) in RO and MD processes with bilge water (conductivity 44.8 mS/cm).

Conclusions

MF experiments with ceramic membranes showed a highly stable permeate flux over increasing VCR and an ease to recover RO membrane performance if bilge water was pre-treated with a MF process. The conducted experimental study of RO and MD processes for treatment of microfiltrated bilge water, revealed advantages of membrane distillation over reverse osmosis.

MD was characterized by a much higher permeate flux and an excellent permeate quality (low and constant conductivity, COD and TOC). It was shown that the MD process can be effectively implemented for treatment of RO concentrate of bilge water to increase water recovery and to obtain high quality water for reuse.

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